Solid-State Lightning Field Sensor

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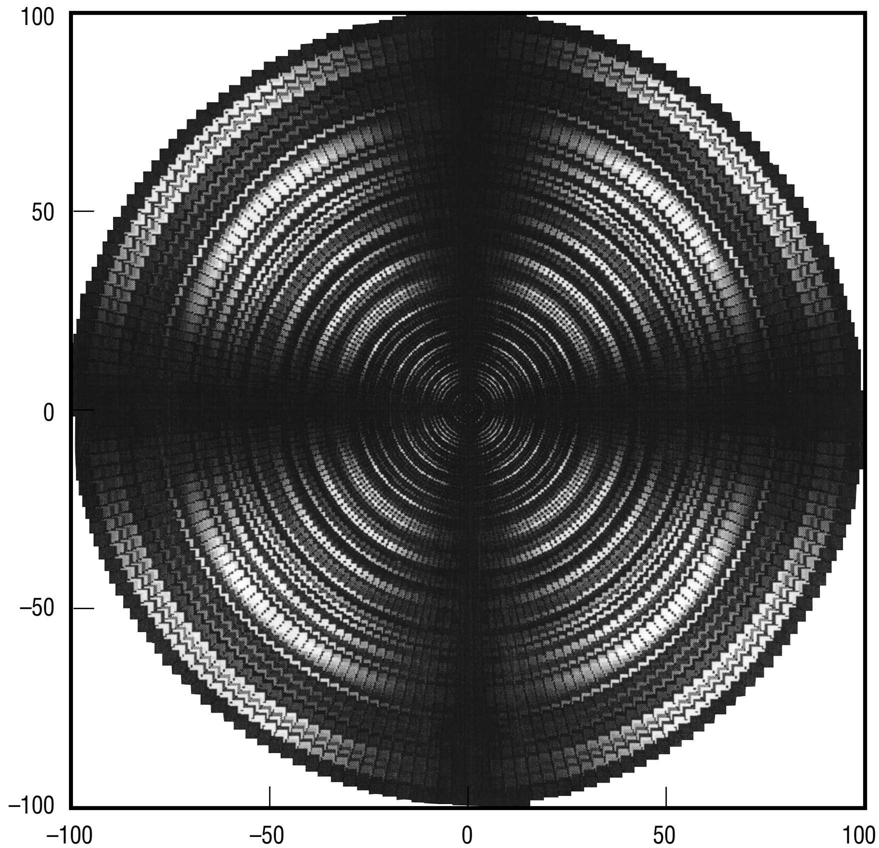

Figure 161.—Diffuse crystal output showing the isogyre pattern for a perfectly aligned optical system.

The primary goal of this project is to develop a new, ground-based, solid-state instrument for detecting thunderstorm electrostatic fields. An attempt will be made to extend detection into radio frequencies.

Electric field measurements are fundamental in diagnosing the electrical state of the atmosphere and the potential for lightning. Some adverse effects of lightning include: human fatality, electric power outages, forest fires, and hazards to aircraft and space vehicle operations. The NASA Kennedy Space Center (KSC) and the USAF Eastern Space and Missile Center (ESMC) currently operate and maintain a ground-based electric field mill network as a lightning warning system for space vehicle operations, including launch protection. Field mills and antenna systems that detect electric field changes represent the primary means for detecting lightning and other electrical phenomena in the atmosphere.

Generally speaking, these devices employ a flat plate antenna which, when exposed to the ambient field, becomes polarized. The amount of polarization charge induced on the plate is related to the ambient field strength. The induced charge (or current) can be amplified and recorded.

Anisotropic electro-optic crystals offer a different approach to sensing small electric fields. When a voltage is placed across a crystal (e.g., potassium di-hydrogen phosphate (KH_2PO_4, also known as KDP), barium titanate ($BaTiO_3$)) the refractive indices of the crystal change in a particular way. This change alters the polarization state of a laser light beam propagating down the crystal optic axis. Hence, with suitable application of vertical and horizontal polarizers, a light transmission measurement can be related to applied crystal voltage (or electric field across the crystal). This is the basis of the solid-state lightning electric field sensor.

During the past year, all critical optics (i.e., KDP, polarizers, retarders, laser, filters, detectors) were procured and assembled, and a data acquisition system was integrated for breadboard testing of the crystal. In addition, fabrication of a three-axis crystal holder was completed for preliminary alignment tests. These tests were conducted by illuminating the crystal with a diffuse beam and inspecting the diffuse crystal output with a screen. The output of an aligned optical system is that of an isogyre pattern. Such a pattern was reproduced in the laboratory and was used to help align the optical system. Based on these tests, recommendations for final crystal holder requirements were completed and procured.

Preliminary sensitivity tests were conducted using the optical breadboard system, a 12-bit DT2833 analog-to-digital board, and Microcal Origin data acquisition software. The investigators completed the first vital step in verifying the presence of the electro-optic effect in the test crystal.

In future months, the investigators plan to continue upgrading the crystal performance. The parameters associated with crystal alignment shall be optimized. A crystal holder with micrometer adjusts and a new vendor-sealed/electrode-installed KDP crystal will be obtained. Sensitivity shall be optimizated by adjusting the orientation of the polarizers and a quarter wave retarder plate. In addition, dc optical offsets will be removed to eliminate overranging when photodetector amplifier gain is increased. An attempt to reduce the dc components by simple electronic means will also be investigated.

Pending further sensitivity improvements, the prototype electro-optic field sensor shall be deployed to collect thunderstorm data at NASA/MSFC. Because solid-state technology is used, future designs of the sensor can be largely scaled down in physical dimension, making them an attractive alternative to standard measurement techniques. In addition, sensor gain can be controlled by adjusting laser power, laser wavelength, or crystal properties and therefore is not limited to purely electronic means of amplification.

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University Involvement: Co-investigator Dr. Richard Solakiewicz, Chicago State University

Biographical Sketch: Dr. William Koshak is an atmospheric physicist within the Earth System Science Division of MSFC's Science and Engineering Directorate. He supports lightning research activities as part of the Global Hydrology and Climate Center (GHCC) cooperative agreement. He received a Ph.D. from the University of Arizona, Institute of Atmospheric Physics, in 1990.